Field Investigations of Lactate-Stimulated Bioreduction of Cr(VI) to Cr(III) at the Hanford 100H Area

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RESEARCH OBJECTIVES

Field investigations have been performed to assess the potential for immobilizing and detoxifying chromium-contaminated groundwater, using lactate-stimulated bioreduction of Cr(VI) to Cr(III), at the Hanford Site's 100H Area.

APPROACH AND METHODS

Lactate (Hydrogen Release Compound—HRC™) injection into chromium-contaminated groundwater is expected to cause indirect or direct bioreduction of chromate, Cr(VI), and precipitation of insoluble species of Cr(III). At Hanford 100H, two new wells were completed using a newly developed assembly with inflatable (argon gas) rubber packers, groundwater samplers, and an inner geophysical access tube. Pre-HRC injection and post-HRC injection geophysical (seismic and radar) cross-borehole measurements were performed (see a summary by Hubbard et al., 2005 [this volume]). Forty pounds of ^{13}C-labeled HRC were injected into Well 699-96-45 (44–50 ft within the Hanford formation) on August 3, 2004, immediately followed by pumping (which continued until August 30) from the Monitoring Well 699-96-44.

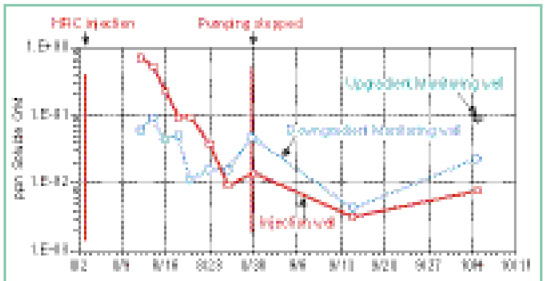

Figure 1. Changes of Cr(VI) concentration in injection and monitoring well resulting from HRC groundwater biostimulation

Groundwater analyses included: Acridine orange direct counts and molecular analyses—PLFA, 16S GeneChip, clone library, qPCR, bromide (tracer added to the injection well), chloride and phosphate (added to HRC), acetate (byproduct of HRC microbial metabolism), nitrate and sulfate (present in background groundwater), Cr(VI), total Cr, and Fe(II), total Fe, carbon, nitrate, and oxygen isotopic compositions.

ACCOMPLISHMENTS

Groundwater biostimulation caused microbial cell counts to increase from a background of ~10^5 cells g^{-1} to reach a maximum of 2×10^7 cells g^{-1} 13 to 17 days after the injection. This maximum lasted for 2 months and then decreased to values even less than those under pre-HRC-injection conditions. Biostimulation also generated highly reducing conditions: DO dropped from 8.2 to 0 mg/L, redox potential from 240 to -130 mV, and pH from 8.9 to 6.5. After pumping stopped and the system returned to natural regional groundwater flow, DO, redox, and pH began to recover to background values. PLFA and direct counts both indicated similar biomass changes. Carbon isotope ratios of DIC decreased, but remained for 6 months above background in Well 699-96-44 and within the injection interval in Well 699-96-45—until December 2004. The $\delta^{13}C$ ratios in dissolved inorganic carbon confirmed microbial metabolism of HRC. Geophysical investigations show that HRC products (such as lactic acids) injected into groundwater can be detected using radar and seismic survey, and that even small variations in hydrogeological heterogeneity may influence the distribution of the amendment and its products.

Hydrogen sulfide production was first observed after about 20 days post-injection, which corresponds with the enrichment of a *Desulfovibrio* species (sulfate reducer) identified using 16S rDNA microarray and monitored by direct fluorescent antibodies. DO and nitrate began to return to background concentrations two months after HRC injection, despite groundwater bacteria densities remaining high (>10^7 cells/mL).

As a result of groundwater biostimulation, Cr(VI) concentrations in the monitoring and pumping wells decreased below drinking water minimum-contaminant limits and remained below upgradient concentrations, even after 6 months (Figure 1), when redox conditions and microbial densities had returned to background levels.

SIGNIFICANCE OF FINDINGS

Microbial, geophysical, and geochemical analyses of groundwater, coupled with stable isotope monitoring, allowed for accurate tracking of microbial processes during this field treatability study, and confirmed that Cr(VI) was successfully removed from groundwater at a contaminated site using HRC as an electron donor and carbon source.

PROJECT WEBSITE

http://www-esd.lbl.gov/ERT/hanford100h/index.html

RELATED PUBLICATIONS

Hubbard, S., K. Williams, J. Peterson, J. Chen, B. Faybishenko, and T. Hazen, Geophysical monitoring of HRC distribution in groundwater during a Cr(VI) bioreduction experiment at the Hanford 100H site. This Volume, 2005.

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